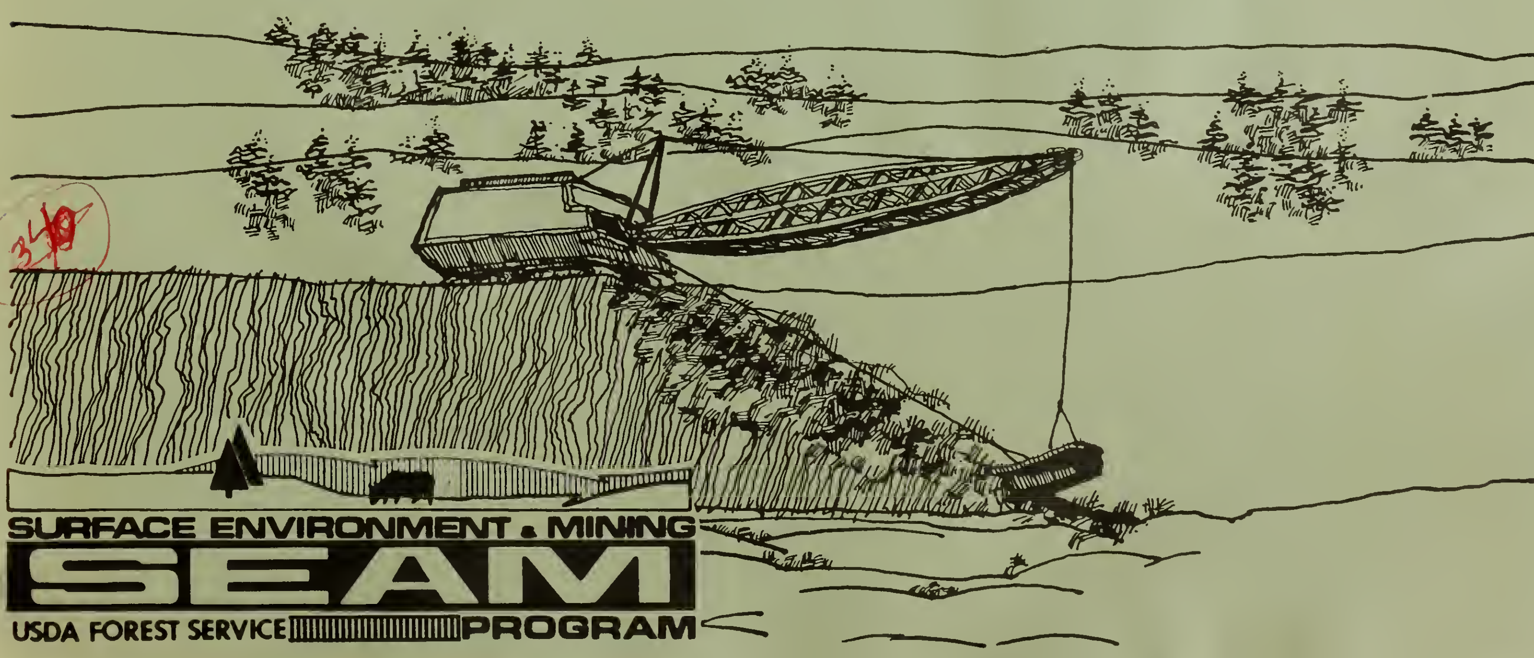
AMPLAN OVERVIEW

USDA Forest Service
Intermountain Forest & Range
Experiment Station

Montana State University
Department of Industrial
Engineering/Computer Science

Vol. I No. 1 Oct. 1979



SURFACE ENVIRONMENT & MINING
SEAM
USDA FOREST SERVICE PROGRAM

SEAMPLAN

OVERVIEW

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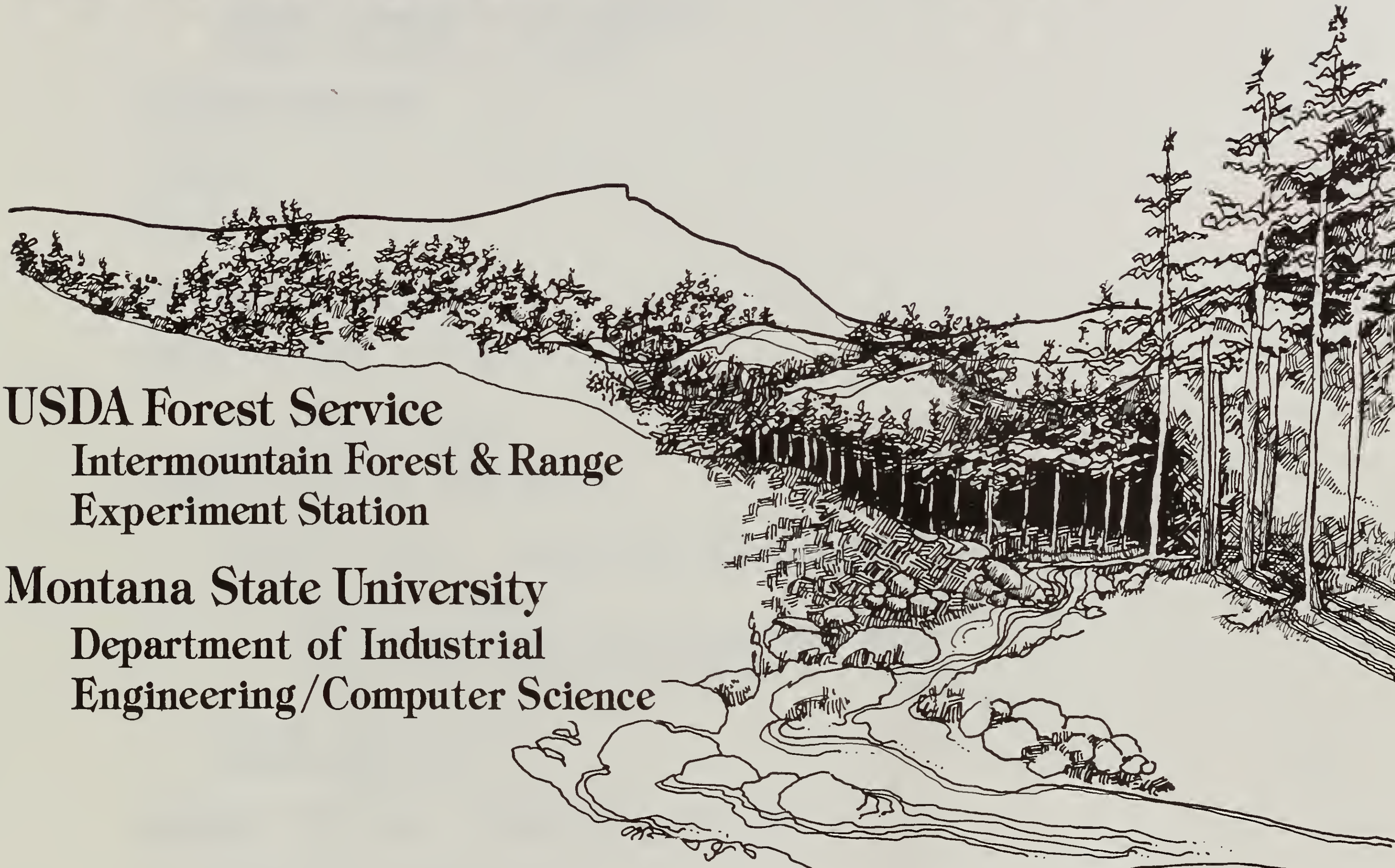
SEAMPLAN
OVERVIEW



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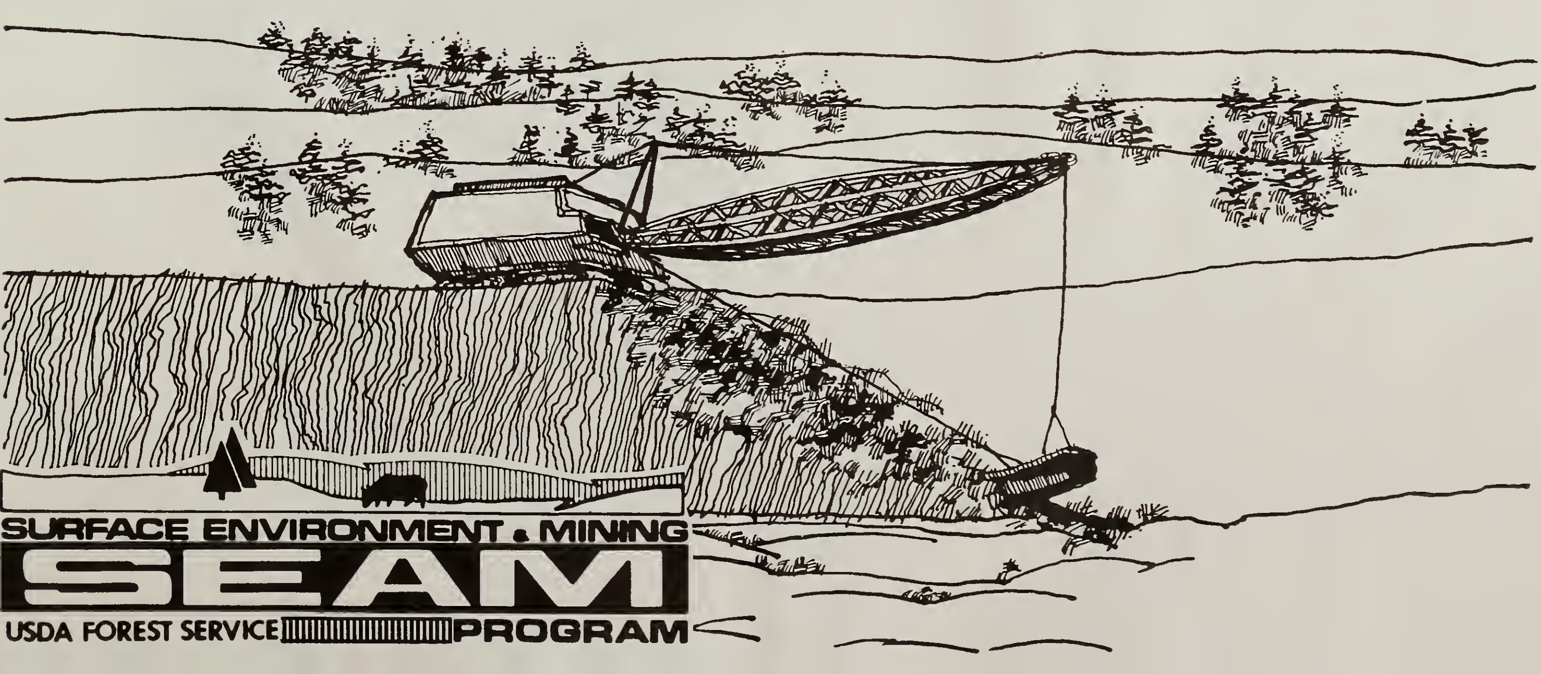

SURFACE ENVIRONMENT & MINING
SEAM
USDA FOREST SERVICE PROGRAM

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GENERAL COMMENTS--ALL VOLUMES

The Surface Environment and Mine Planning System (SEAMPLAN) reported in three volumes, provides an integrated computerized planning system for evaluating surface coal recovery consistent with minimal impact on environments.

The SEAMPLAN System was developed on a Hewlett-Packard minicomputer using the RTE III operating system in a highly modular software design. Its organization revolves around three functional modules:

1. Data Entry and Review
2. Production Analysis
3. Impact Analysis.

Each module is divided into programs combining a users' knowledge gained through interaction with information found in standard data files. In this way an unfamiliar user is quickly provided with a broad range of computing capability.

In addition to Roman numeral designation, all three volumes in SEAMPLAN are given Arabic numeral "1". Future reports, which include new, but related material, or elaborations and other extensions of current material, will be given sequential Arabic numeral designations.

Volume II (USER'S GUIDE) is a stand alone manual giving step-by-step procedures for a manager, engineer, or interested user to successfully apply SEAMPLAN without benefit of selecting and setting up a system or without in-depth knowledge of the mathematical modeling and computational logic internal to it.

Volume III (SEAMPLAN Program Documentation) is a stand alone manual giving a broad overview of all programs in SEAMPLAN. Program descriptions and logic are included where necessary. Data layout charts show types of data used in programs and how they are input and output. An appendix contains system routines.

GENERAL COMMENTS--VOLUME I

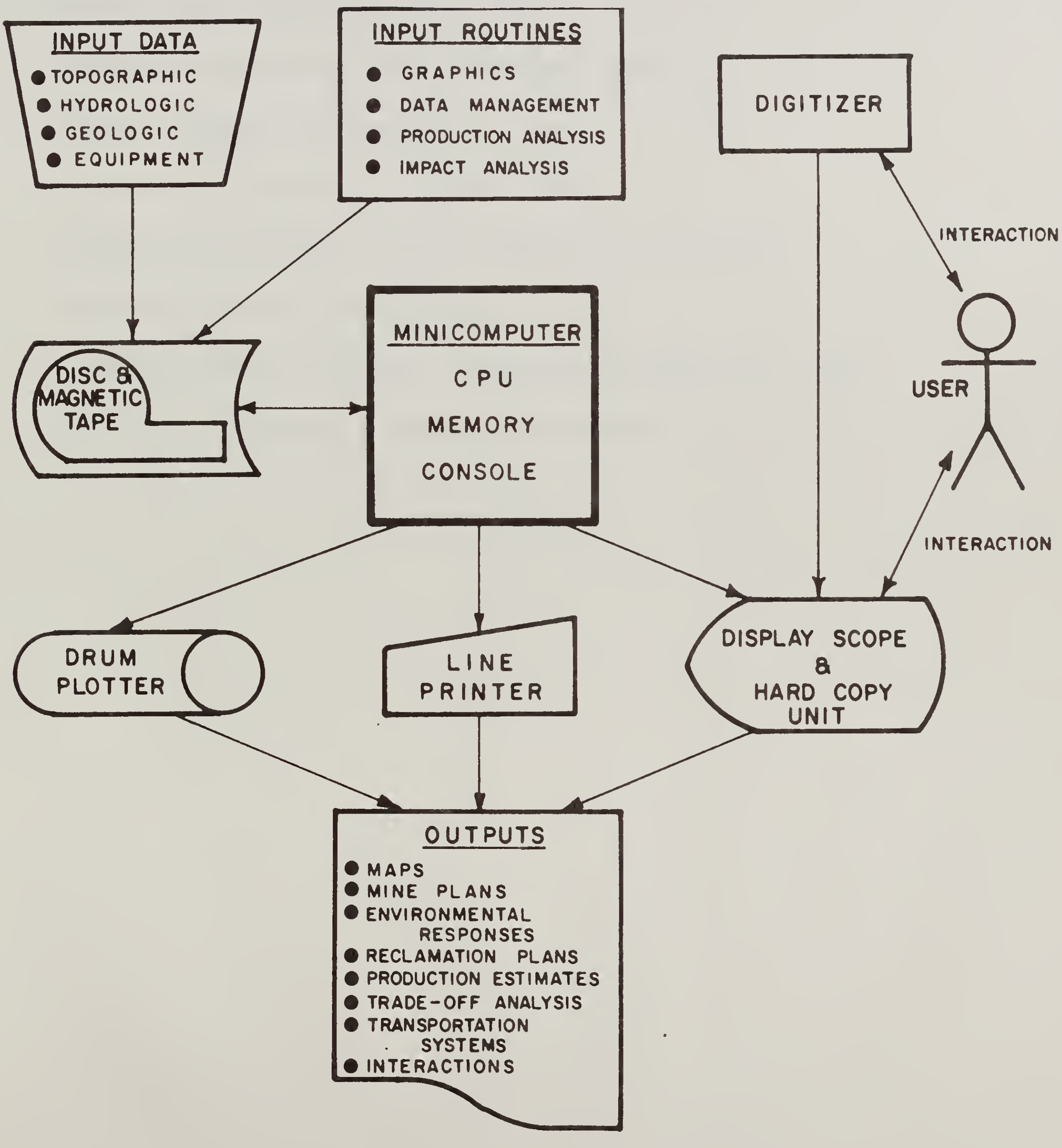
The major purpose of the OVERVIEW is to describe acquisition, adaption

and development of the applications software. This overview should assist the potential user in selecting equipment for setting up a project and applying the programs.

In support with the above, a history of the surface mining plan and a sequence of operational events are given.

OVERVIEW GUIDE MAP

*FAMILY INTERRELATIONSHIPS OF CATEGORIES DISCUSSED IN VOLUME I.



FIGURES

TABLES

INTRODUCTION SECTION I

The 1973 Arab Oil Embargo emphasized the United States' dependency upon imported oil as a primary energy source, but the Carter administration has outlined plans to lessen this dependence. A key element of these plans involves a dramatic increase in coal production with a goal set of 1.2 billion tons per year by 1985.[1] This represents essentially a doubling of the 672 million tons produced in 1977. To a large extent, whether or not this goal can be achieved is a function of mine productivity and governmental policies regarding factors such as taxation, reclamation, and incentives to industry for conversion.

Figure 1 shows the projected coal production required to meet the 1985 goal. Estimates indicate that about 59% of the 1985 production will be from surface mines. This means approximately 500 out of 800 million tons (62%) of coal coming from mines opened after 1974 will come from surface mines.[2]

While increased surface mining activity offers the obvious benefit of increased energy supplies for our economy, one must not overlook the environmental problems that will result. If we are to enter a second coal age we must simultaneously develop methods to mitigate the site disturbances which accompany surface mining activity.

The renewed emphasis on coal as an energy source has spawned legislation aimed at regulating reclamation practices. In addition, funds have been allocated through many governmental agencies for research aimed at improving both recovery and reclamation technologies applicable to surface mines. One such research effort is the SEAM (Surface Environment and Mining) program sponsored by the USDA Forest Service and EPA. SEAM'S mission is to develop and apply technologies that create increased coal production while preserving environmental quality. Although many SEAM researchers are involved in more basic research, this report describes a minicomputer based, interactive, mine planning system of a more technical nature. By integrating results from a variety of sources, the system enables planners to evolve mine plans meeting stated production and cost objectives while simultaneously considering trade-offs between productivity and environmental protection.

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1. The National Energy Plan, Executive Office of the President, Energy Policy and Planning, April 29, 1977.

2. Graham, Robert J., "Planning of a New Surface Mine - Western Coal," Mining Congress Journal, June, 1977.

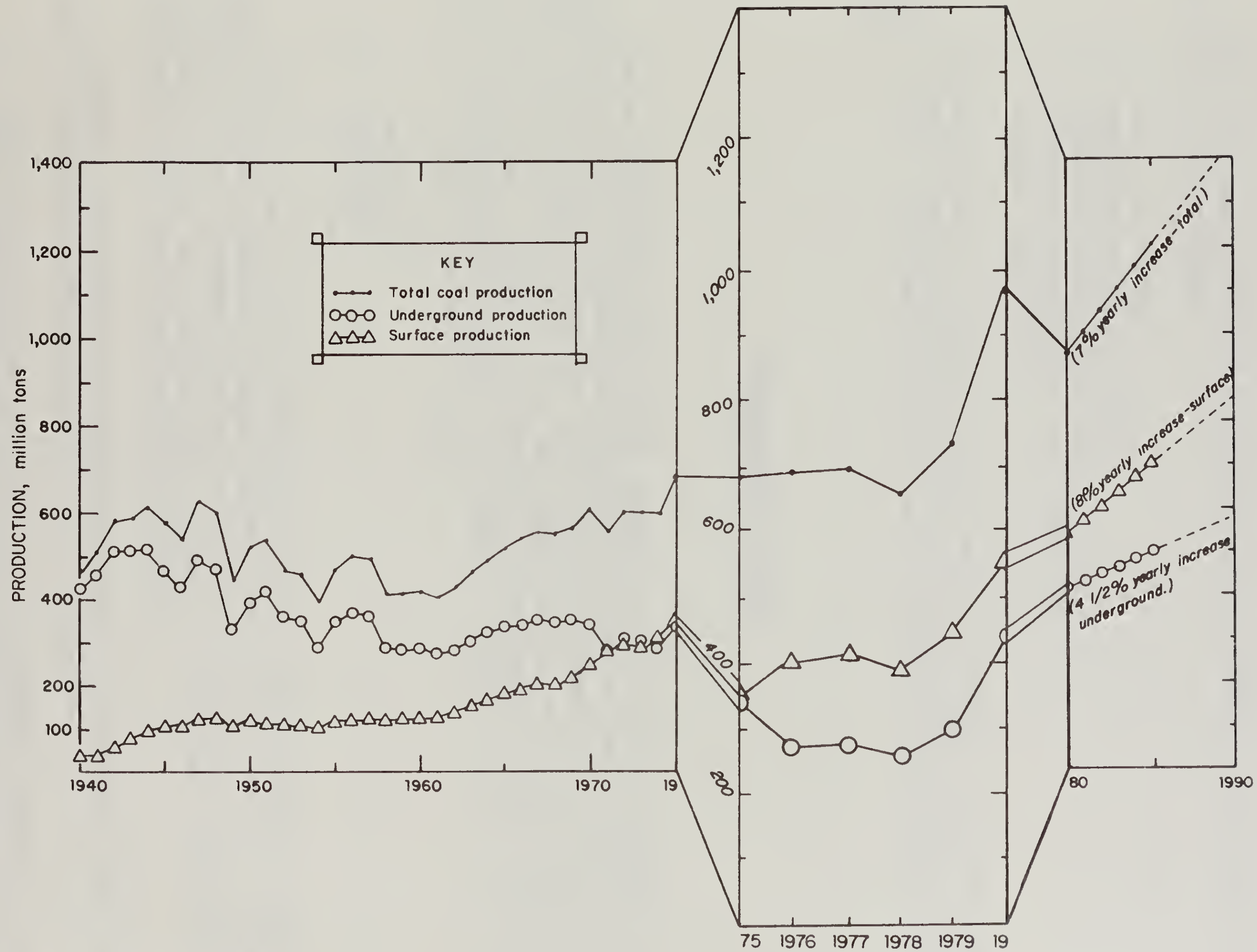


FIGURE 1.-- PROJECTED COAL PRODUCTION

The development of SEAM planning system, SEAMPLAN, has been accomplished in five major phases:

1. Goals definition
2. Preliminary system design
3. Computing source and hardware selection
4. Hardware installation and shakedown
5. Program development.

Project goals as initially stated were to provide the land (mine) manager with a comprehensive tool for use in evaluating surface coal mine plans. Later, this broad objective was translated into several sub-objectives.

PRELIMINARY DESIGN

Having identified objectives, members of the project formed a logical description of the envisioned software/hardware system. A preliminary design focused largely upon the mine planning process specifying a software module at the first level of a "top down" design needed for computerization of this process. Figure 2 illustrates the planning process for surface mines, computerized or manual. As shown, a typical surface coal mine progresses through three major stages:

1. Exploration
2. Planning
3. Operation.

Dotted lines indicate information flow. The exploration stage provides much of the data needed by mine planners, while the planning process itself largely involves presentation and analysis of the data. Also, planning is interative; plans are continuously updated as additional information from operations and further exploration surfaces.

Figure 3 illustrates essential features of the computerized planning system. Its basic input falls into four categories:

1. Core or drill hole data taken at the property provide a description of the physical and chemical conditions under which mining might occur. Information extracted from drill hole data could include such things as depth of overburden, thickness of coal, and various qualities and characteristics of each.

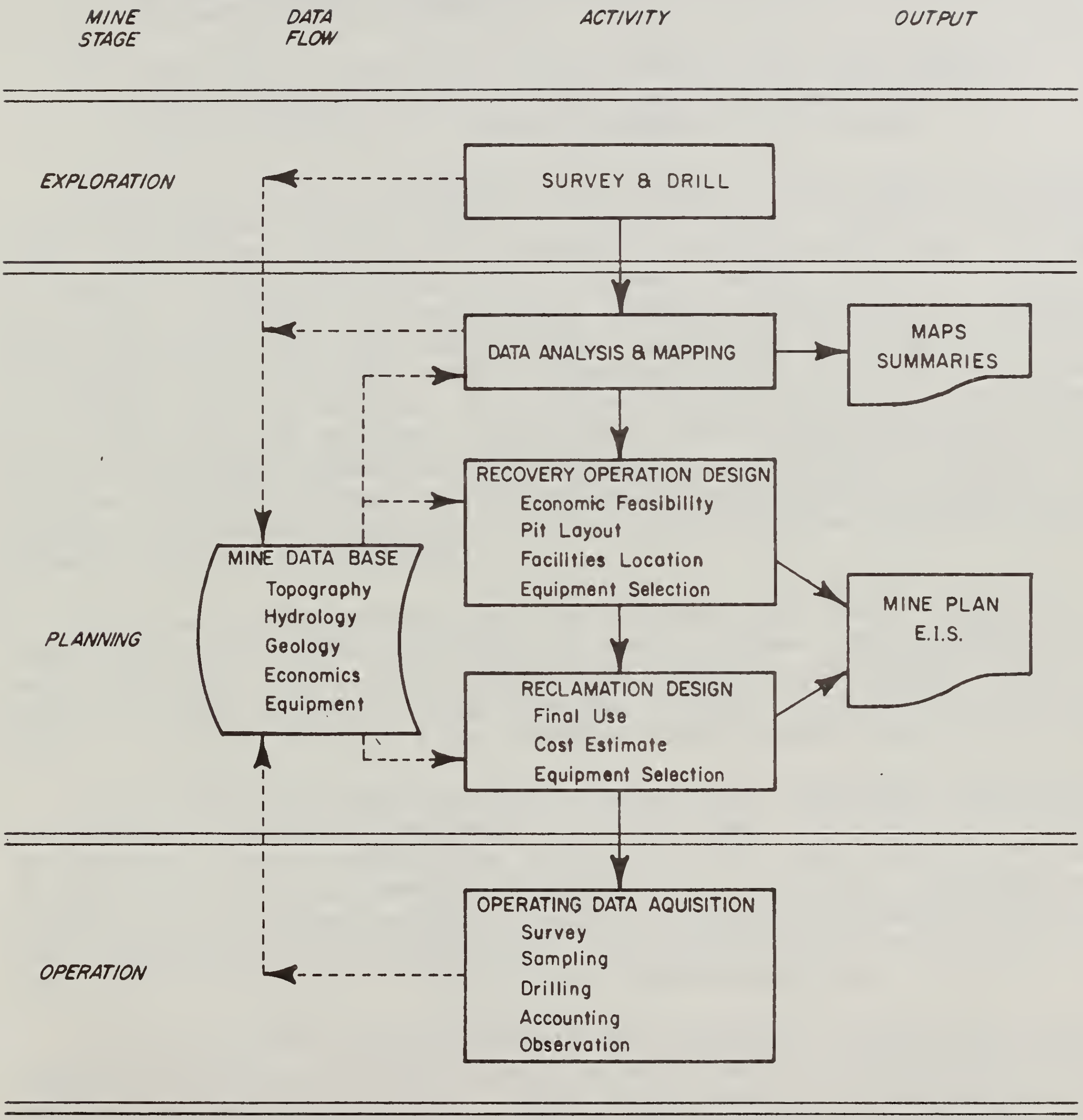


Figure 2.-- Planning Process for Surface Mining.

2. Production, capital requirements, and general information necessary to operate a business are needed. Examples might be required tons/year, minimum rate of return, or projected selling price of coal.

3. Restrictions related to environmental protection or set by management objectives must be known, particularly those set by state and Federal laws. These may constrain such things as basic mining operations, methods of spoiling overburden, and methods for reclamation.

4. Site data are necessary such as climate, soil type, hydrologic information, etc., which are used to estimate environmental impacts and to develop reclamation strategies.

Once basic input are provided to the system, a large array of computational and mapping routines become available to user. Displays of the geology, stratigraphy, and various properties of the overburden and coal could be made in the form of 3-dimensional surfaces, contour plots, bar charts, and others. Listings and computational summaries of physical and chemical characteristics of the area can be found. If desired, the user can zoom in on various parts of an area under consideration and get information in whatever detail and form desired. The primary purpose of this part of system is to allow the user to recall, manipulate, and display information to assist in the design, production, and reclamation operations of mining. In addition, various computational and mapping routines greatly facilitate the process of providing regulatory agencies with information concerning both property and planned operations.

Note that data management and graphics functions shown in Figure 3 underlay or are embedded throughout the entire system. These blocks represent techniques used to store, manipulate, retrieve, and display large amounts of data required for mine planning efforts. Although they are "invisible" to a user, they are a very important and integral part of the system.

After obtaining various maps and computational summaries, development for applying a production analysis module follows. The module is really an interactive, computer-aided, mine design tool. The user can call on a group of models that optimize dragline design relative to various criteria; he can specify his own designs and have a series of computations made; or he can use a combination of both approaches. In addition, first order specification can be obtained for other recovery related operations.

Having specified recovery methods and equipment, the user may analyze reclamation methods in a multi-level fashion similar to an approach for investigating dragline stripping. Using output from the production analysis module and data specifying environmental limitations, the feasibility of a desired strategy may be evaluated. Next, programs to estimate reclamation costs and equipment mix can be executed. Feedback shown in Figure 3 to production analysis includes cost and feasibility information. Hence, the planner may iterate between production and reclamation design activities until a balance is achieved between increased recovery cost and lower reclamation costs. Also, the user may discover that the "least cost" recovery

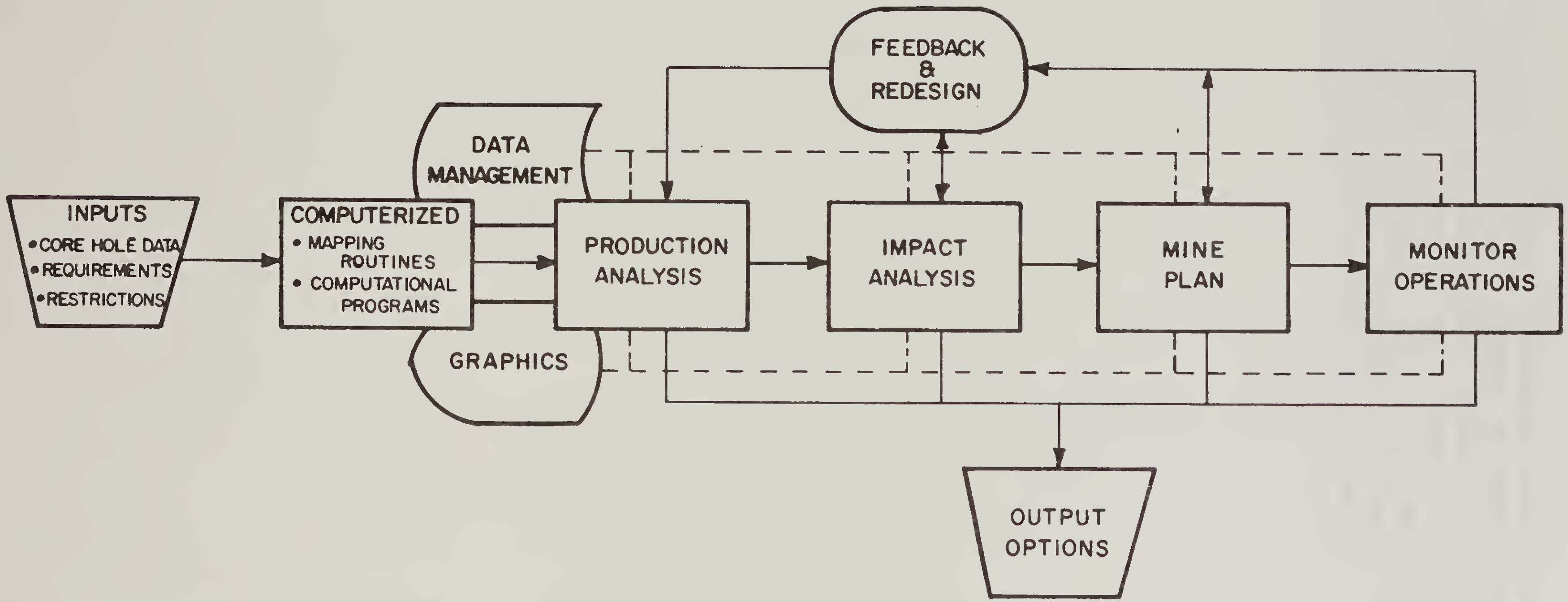


Figure 3.-- Proposed Mine Planning System Logic.

plan unduly restricts reclamation options and will cycle back to production analysis to respecify mining activities until desired reclamation goals are met.

The final block of the diagram represents another use of the system; namely, that it is valuable not only during the mine planning stage, but can monitor activity after mining begins. Keep in mind that the original plan may have to be modified since area features, market conditions, equipment, and methods constantly change. The system can handle these contingencies and, thus, becomes a highly functional management tool during the entire spectrum from planning to actual mining operations and ultimately through reclamation.

Following preliminary design, which consisted of specifications for an integrated, interactive, mine planning system, it became clear that project personnel would be involved in construction of a "virtual computer" for surface mine planning. This "machine" would consist of a nucleus of general purpose computing hardware and systems software linked to the user through various peripherals, in turn driven by integrated applications programs.

The hierarchic concept is illustrated in Figure 4 where the total system is viewed as a series of concentric rings. Each ring represents a level in the hierarchy of the total machine, where the innermost ring (lowest or elemental level) consists of the basic computing unit. Initially, the two inner rings and the outer ring were considered within the context of the logical system design. That is, since the rings (elements) form the basic building blocks of the "virtual machine", their selection and installation preceeded development of the applications software ring. Hence, a brief discussion of system hardware, software, peripherals, and their selection is given before a discussion of applications software.

Once the logical framework for the computerized system had been established, designers were ready for the next phase of the project. The nature of the data and design criteria and their interactivities meant that selection of an adequate source of computing (represented by the inner ring, Figure 4) would be critical for project success. Therefore, with a requirement for first level applications software in mind, the next step was to determine a computing source and select necessary hardware.

COMPUTING NEEDS--IDENTIFYING ALTERNATIVES

During initial system development, provision of adequate computing was critical. Based on desired uses, three computing postures were identified:

1. High resolution interactive graphics
2. Scientific and engineering computation
3. Massive data storage and retrieval.

Each posture places unique requirements on the computing facility selected, and when considered as a set, the designed system must simultaneously provide capability for all.

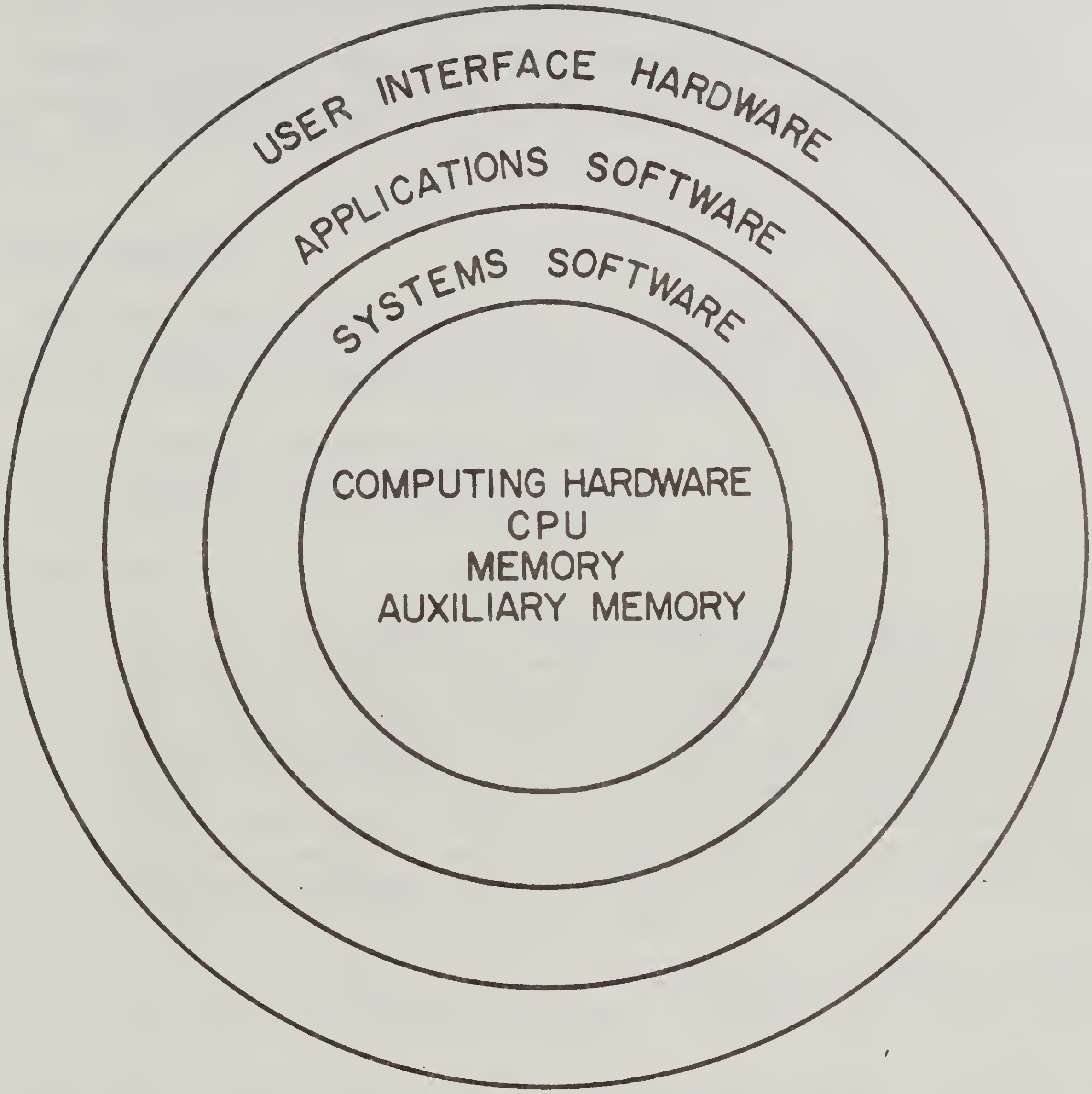


FIGURE 4.-- COMPUTING HIERARCHY
(VIRTUAL COMPUTER CONCEPT).

With computing needs defined, possibilities for providing required capabilities were considered. Three basic options were identified:

1. External time shared systems (external to Montana State University, the research site)
2. Montana State University Computing Center (MSUCC) facilities
3. A stand alone minicomputer system.

These alternatives were evaluated relative to two major criteria, interactive capability (principally graphical I/O), and user accessibility. Other minor factors were cost, accuracy, communications, and support services.

EXTERNAL COMPUTING

The USDA Fort Collins Computing Center (FCCC) was first choice for purchasing external computing services from their UNIVAC 1108, a large, scientific computer. Advantages of this alternative were:

1. Increased computational accuracy
2. Extensive center support
3. Forest Service employee familiarity.

Disadvantages were:

1. Slow turn-around time... During evaluation the FCCC and its communications hardware were heavily overloaded... User costs skyrocketed from delayed response and computer unavailability... This situation prompted the USFS to study an alternative for decentralized computing... If slow turn-around was the only disadvantage, use of FCCC may have been justified with high cost savings. Before undertaking a detailed cost analysis, capabilities were assessed relative to uses... It was found that the planning system under development puts a premium on interactive graphics as a communications medium with the user.

2. Interactive graphical input capabilities are not easily provided with large time-sharing machines... In addition, hardware was needed.

3. Most likely, a minicomputer would have been used as a "front end" communications link to UNIVAC, with the mini taking over interactive graphics functions... Estimated costs for this alternative ran in excess of $10,000 for hardware alone.

4. Additional software and personnel would have been necessary causing delays and project changes.

5. Even with a mini, graphics terminal, and software, certain characteristics of the FCCC time-sharing operating system would probably have made the operation infeasible and most certainly too slow... Slow interactive response would have been very costly during development and application.

MONTANA STATE UNIVERSITY COMPUTING CENTER

MSUCC was the second alternative considered. The machine is XEROX'S SIGMA 7, a medium sized computer with slightly less computational accuracy than the UNIVAC 1108. Library and scientific support are comprehensive. The system is used for a variety of educational, scientific and data processing applications. MSUCC had several advantages over the external computing alternatives (FCCC):

1. Proximity - researchers are "next door" to the computer and enjoy favorable rapport with the computing center staff... Over 50 terminals are serviced on campus with remote use from several locations.
2. A graphics capability (limited input) is maintained by MSUCC.

Disadvantages were:

1. Slow turn-around during peak loads because of heavy instructional use... I/O ports difficult or impossible to access during peaks ... Problem severe about two weeks each quarter, but did not prevent consideration of MSUCC.
2. Interactive graphics problems expected to be similar to those of external time-shared machines... Efficient handling of line drawing from a tablet (graphical input) required a "front end" mini... The SIGMA 7 cannot "listen" to the tablet often enough to save and interpret all input from it... In addition, picture refresh (write through) cannot be performed effectively in such an environment when a shared CPU must do this function.

STAND ALONE MINICOMPUTER SYSTEM

The third alternative, a stand alone minicomputer system, was found to be the most cost effective:

1. Dedicated real-time capability
2. Reduced expense for purchasing computing time
3. Hardware reliability.

Disadvantages were:

1. Maintenance expense of both hardware and systems software
2. Machine limitations (smaller capacity)
3. Lead time necessary for installation and start-up
4. Initial investment cost.

The mini computer system was finally selected to accomplish synthesis of graphics, data management, and analysis of software into a user oriented, highly interactive planning system.

SYSTEM SPECIFICATION

Now that the basic configuration of the minicomputer system was specified, material describing available equipment was solicited from vendors. With this material and also information gathered from users, a screening process was conducted for the most likely manufacturers. Three vendors were identified as potential suppliers of all or part of specified equipment, exclusive of graphics equipment, which were selected separately.

During generation and evaluation of alternatives, the configuration of a stand alone minicomputer system was outlined. Figure 5 shows the system components specified, and Table 1 describes the minimum capabilities required. The system proposed consisted of the CPU with 64,000 words of memory, a 9 track magnetic tape drive, a small line printer, and a 5 megabyte (5 million characters) cartridge disc with associated disc operating system software. Specified peripherals were a graphics subsystem consisting of a high resolution (limited refresh) terminal, a hard copy unit, and a tablet for creation of permanent, detailed computer generated drawings. Later, a larger 50 megabyte, multiplatter disc-pack unit was also added to the system.

VENDOR SELECTION

Selection of the vendor(s) was done on a cost/benefit basis. Each system quoted was evaluated relative to three major components.

1. Hardware
2. Peripherals
3. Software.

Figure 6 is an excerpt from the "Request for Quote" (RFQ) sent to each vendor. Shown are the relevent and desirable characteristics with quality points assigned for the cost/benefit analysis. Each manufacturer quoted a system which met or exceeded minimum design requirements. Features were rated and points assigned according to final system application. Alternatives were compared using the cost/benefit ratios (cost divided by total points given).

In addition to hardware and software specification ratings, each vendor supplied performance data for the system quoted. There were two parts to this RFQ. In the first part, vendors were asked to estimate typical times (best/worst) for various arithmetic operations. Next, two bench mark programs were supplied in FORTRAN IV and vendors were asked to furnish information regarding computing time and memory requirements for both compilation and execution. This information was used as an aid in evaluating the hardware/software trade-offs for each relative to project needs.

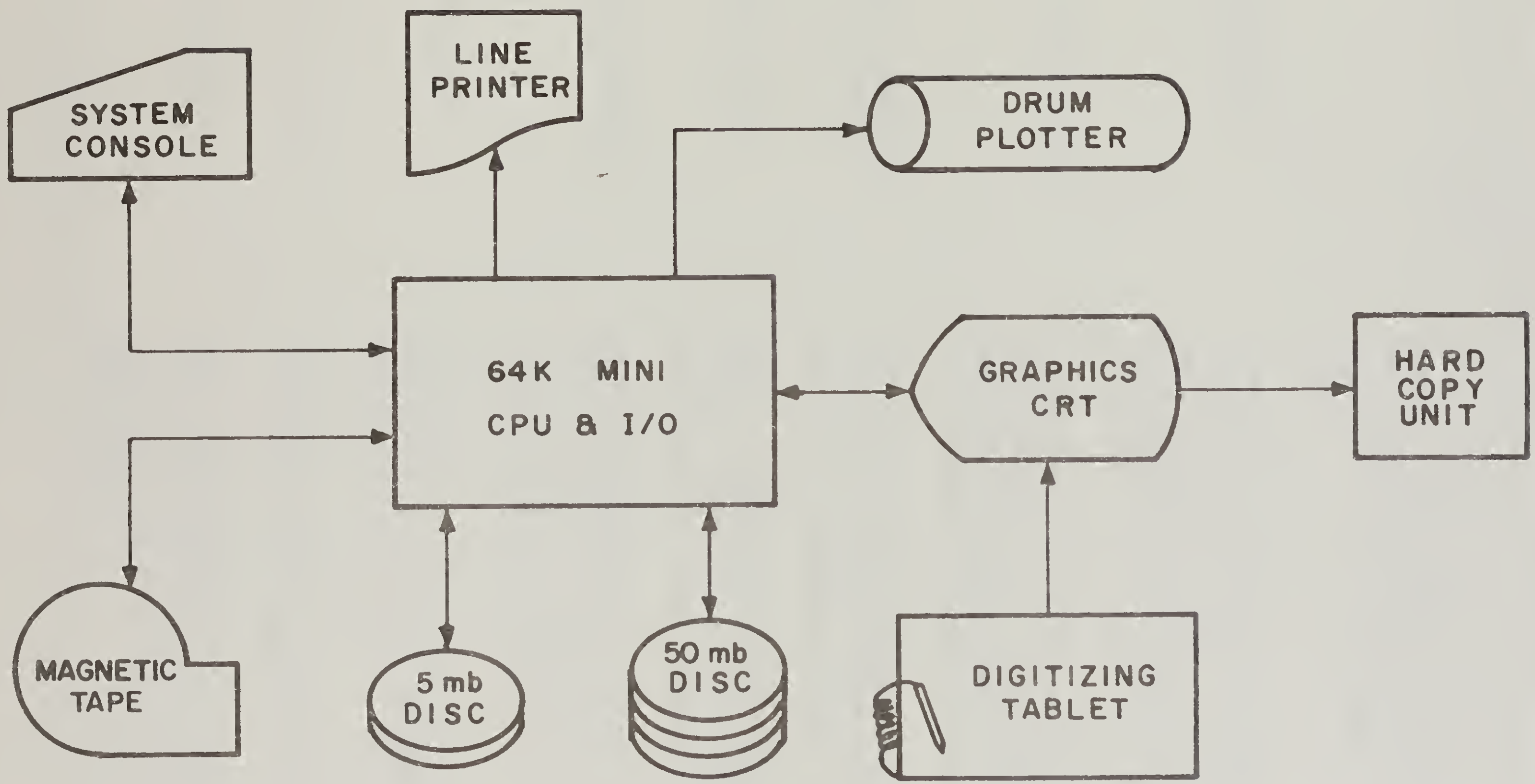


Figure 5.-- Computer Hardware Schematic.

TABLE 1. -- SYSTEM SPECIFICATIONS

ITEM	GENERAL SPECIFICATIONS AND USE
Minicomputer & Memory	64K, 16 bit words of memory (semiconductor or core), direct memory access I/O, hardware divide and multiply, double word instructions: logic, arithmetic and I/O hardware, the basic system unit.
Cartridge Dist Subsystem	5 megabyte capacity, moveable head; 2 cartridges (fixed and removable), power supply, controller and interface, 200K + bytes/sec. transfer rate; mass storage unit used for operating system, graphical and computational data.
Operating System	Disc based operating system, minimum includes file maintenance, edit, and FORTRAN IV, interactive I/O and device independent I/O assignment; software to manage applications development and operation.
Graphics Terminal and Interface	CRT with vector drawing and limited refresh (write through); minimum Tektronix 4014 class; basic I/O unit for planning package use.
Graphics Tablet	Must be compatible with CRT; both tracking and fixed point input modes; allows input of graphical data and menu selection of program options.
9 Track Magnetic Tape	800 bpi, minimum 37.5 ipm; transport, drive, and controller and interface hardware; used for transfer of mass cartographic and site descriptive data between installations.
Page Printer	80 columns, 240 lines per minute and interface hardware; to provide adequate output speeds for program debug, data listing, etc.
Graphics Software	Software required to interface graphics CRT with the mini; some assembly level; some FORTRAN IV.
Drum Plotter	Plot area minimum 33.1 inches by roll length RS232 interface, 1 per; to create high quality permanent copy of mechanical drawings (mine, maps, etc.)

III. Software	Points	Price
IIIA. Operating System[9]		____
IIIA.1. General		
Core resident module	8	
On line users > 1	8	
Batch	6	
Relocating and linking loader	25	
Multiprogrammed	8	
Text editor capability $\geq$ PDP 10 TECO	8	
Assembler	20	
Macro assembler	10	
I/O device run time assignment	8	
On line debug	8	
Program overlay	8	
Other features - describe	8	
______________________		
IIIA.2 File Management		
Block data access	30	____
Keyed	15	
Sequential random (linked block)	15	
Sequential random (contiguous block)	15	
Record access	20	____
Random	10	
Sequential	10	
Variable length records	10	
IIIB. FORTRAN IV[10]		____
IIIB.1. ANS Standard Compatible	40	
IIIB.2. Logical Device I/O	15	
IIIB.3. Core required (compiler) $\geq$ 16K	20	
IIIB.4. FORTRAN Library $\geq$ 65 functions	15	
IIIB.5. Assembly stmts. per FORTRAN $\leq$ 2 ave.	15	
IIIB.6. Relocatable object generated	15	
IIIB.7. Program controlled segmenting	15	
IIIB.8. In-line Assembly	15	
IIIB.9. In-line MACRO	15	

Figure 6. -- Excerpt from "Request for Quote" (RFQ).

9/ Operating system assumed to be disc-based, to allow on-line program development, editing, and execution, and to provide I/O drives for standard peripherals.

10/ If more than one compiler is included in the package, please describe each one - also specify compiler chosen if such a choice is made.

COMPUTING CAPABILITIES

The objective information discussed provided only part of the basis for the selection of equipment. Subjective judgements were heavily considered also. This is especially true in cases such as this where three closely matched systems, each capable of supplying the necessary minimum computing needs, must be compared; therefore, criteria such as quality, customer support, established maintenance facilities, and others were considered. After evaluating the vendors quotes, equipment was selected and contracts for delivery executed. Separate vendors were chosen for the following parts of the system:

1. Line printer
2. Graphics hardware and software
3. CPU, operating system, tape drive, and memory
4. Operator's console.

Although much of the foregoing discussion dealt with evaluting and selecting components of the minicomputer system, a bigger problem involved choosing the most cost/effective means for providing required computing capabilities. Constantly keeping ultimate project goals in focus was a key part of the procedure already described. This procedure can be summarized in six activities:

1. Definition of computing needs
2. Generation of alternative sources of computing
3. Selection from available alternatives
4. Configuration and specification of computing system
5. Identification of appropriate vendors
6. Evaluation and selection of equipment from computing vendors.

HARDWARE INSTALLATION AND SHAKEDOWN

After acceptance of the winning vendor's bids, the project moved to the hardware installation phase. Although several minor problems emerged during this step, the only significant problem experienced was that of interfacing components purchased from different vendors. Initial shakedown was facilitated by field engineers, and invaluable experience gained by having a member of the research team attend vendor offered courses.

After installation of hardware components, the task of acquisition, adaption, and development of applications software was initiated. A brief description of these programs is the primary purpose of Volumes II and III. This section, however, gives the reader a broad overview of the software.

Figure 7 illustrates the basic organization of the package. As shown, the program consists of modules connected in a highly structured, hierarchical fashion. On the HP 21MX system used for development, modularization of FORTRAN programs may occur at either the "program" or subroutine level. Since no overlay loader is available, segmentation of large programs requires that portions of them be scheduled or swapped under control of the invoking segment. Using this scheme, each such segment must formally be a separate FORTRAN program even though it serves as subprogram within SEAMPLAN. At the higher levels in the tree, modules are generally implemented as swappable "program segments". Communication between programs is handled in a variety of ways, depending on need, and will be described later as each module is discussed. For now, interest lies only in a broad flow of control; hence, mechanisms for transferring control in specific instances are not important.

Returning to Figure 7, each module may consist of other modules, program segments, or subroutines, with each accomplishing a particular unit of work, or function, selected by user. Table 2 describes each module's function. Details concerning the FORTRAN routines comprising each module are described in Volume III of this report.

Transfers within the SEAMPLAN system between modules are controlled through user selection of menu options. For example, when the user starts executing SEAMPLAN, the menu in Figure 8 is presented by the SPLAN module programs. Selection of options 1 or 2 causes control to be transferred to DENRV or ADM respectively -- similarly for each of these modules. Also, execution of a module on the same level can be acomplished only through user controlled returns to a high enough (necessary condition) control level (outer box) followed by selection of necessary menu options.

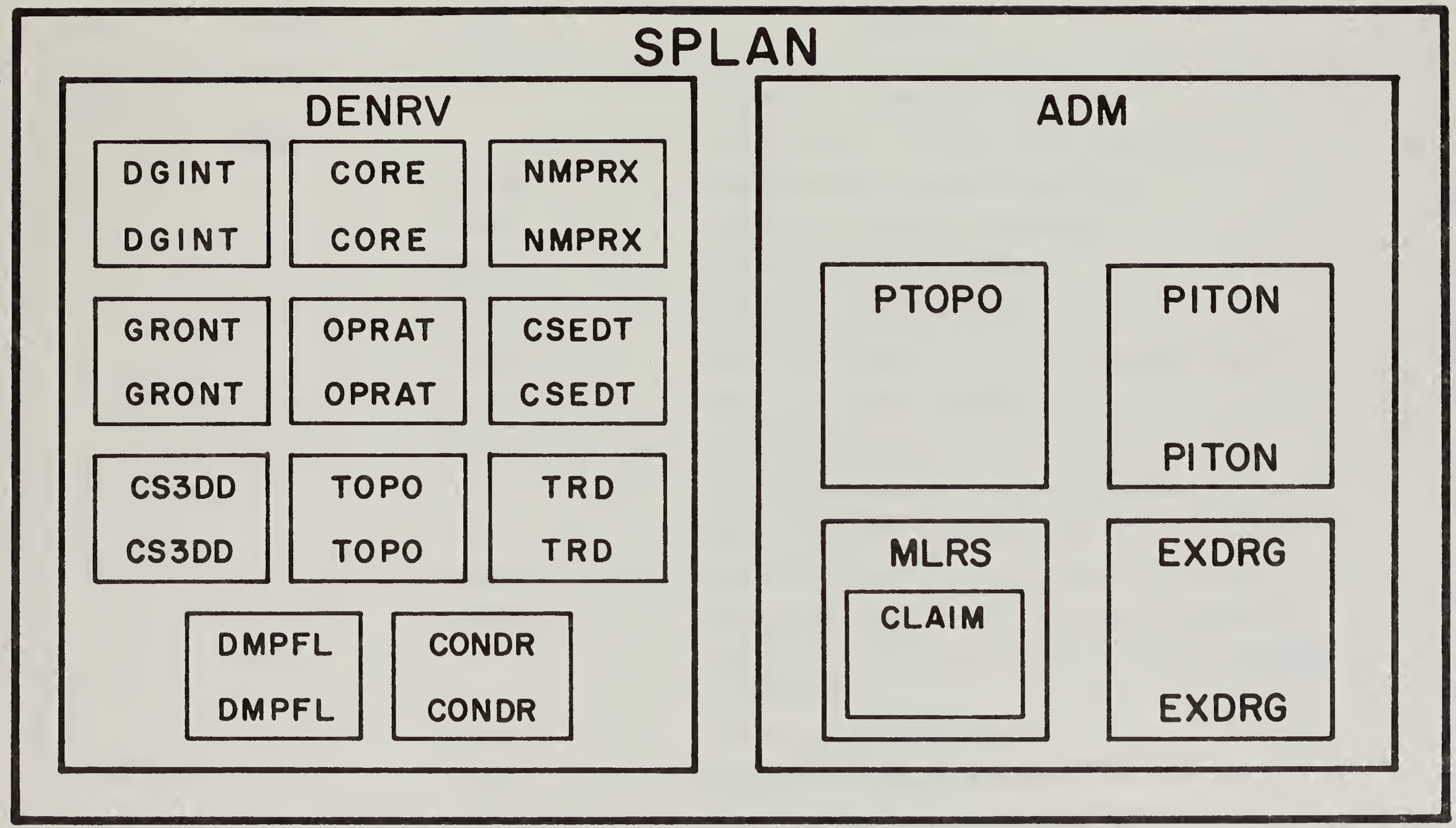


FIGURE 7.-- SEAMPLAN APPLICATIONS SOFTWARE FUNCTIONAL MODULES.

TABLE 2. -- SEAMPLAN Functional Module Definition

LEVEL 1	MODULE 2	SUB-MODULE 3	FUNCTION
SPLAN			SEAMPLAN - executive control
	DENRV		Data Entry - Review module executive
		DGINT	Digitizing function executive
		CORE	Corehole analysis executive
		NMPRX	Grid File Construction
		GRDNT	Grid mesh interpolation
		OPRAT	Grid or binary x, y, z arithmetic operations
		CSEDT	Grid file edit program
		CS3DD	Grid file 3-D section display
		TOPO	Grid file contour map production
		TRD	Grid file 3-D surface display
		DMPFL	Grid or binary x, y, z file print out
		CONDR	Vectored (continuous) map data drawings
	ADM		Production & reclamation control and macro analysis
		PTOPO	Interactive pit layout
		PITDN	2nd level dragline design
		MLRS	2nd level reclamation design & 3rd level control
		CLAIM	3rd level reclamation analysis
		EXDRG	3rd level (simulation) dragline analysis

```
XXXXXXXXXXXXXXXXXXXXXXXXX
X                       X
X  SEAMPLAN EXECUTIVE   X
X   OPTION SELECTION    X
X                       X
XXXXXXXXXXXXXXXXXXXXXXXXX



1 -> DATA ENTRY-REVIEW
2 -> PRODUCTION ANALYSIS
3 -> IMPACT ANALYSIS
0 -> TERMINATE

INPUT -> OPTION ?
```

FIGURE 8.-- SEAMPLAN EXECUTIVE CONTROL MENU.

Computer technological capabilities seem boundless as witnessed by dramatic demonstrations of improvements in industrial efficiency over all sectors. Since our nation may increase its interest in coal production to help ease energy problems, there appeared ample justification for development and application of a computerized planning model for evaluating surface coal recovery.

Volume I describes a search for just such a system. First, a basic design is discussed taking significant variables into account. A building block format for planning a mining system guides the design. Next, a detailed explanation is given to construct a computer system that will fit the design. It should consist of a nucleus of general purpose computing hardware and systems software linked to a user through peripherals (Figure 9). Covered are prospective users' needs, machine choices, vendor selections, steps to take for installation, and shakedown phases. Last is a brief account of the task for selecting, adapting, and developing the applications software, a description of which is the primary purpose of this volume.

TYPICAL PLANNING SESSION

Although procedures for a mine planning session are given mainly in Volume II, the logical extension of mine planning from Volume I to Volume II may be summarized as follows (Figure 10):

1. A classification of system software modules is selected by interactive response with computer (Frame 1).
2. Data are entered into system to describe and give meaningful results to options from Frame 1 (Frame 2).
3. Data may also be visualized in 3 - dimensional displays (Frame 3).
4. Sections may be viewed and grid data displayed and modified by using either digitizing tablet or cross hair cursors (Frame 4).
5. Additional data is required for new categories, again in the spirit of an interactive planning session (Frame 5).
6. The pit layout process fixes mining boundaries (Frame 6).
7. Output is generated by specifying dragline size and pit dimensions (Frame 7).
8. A new option is chosen at conclusion of previous results (Frame 8).

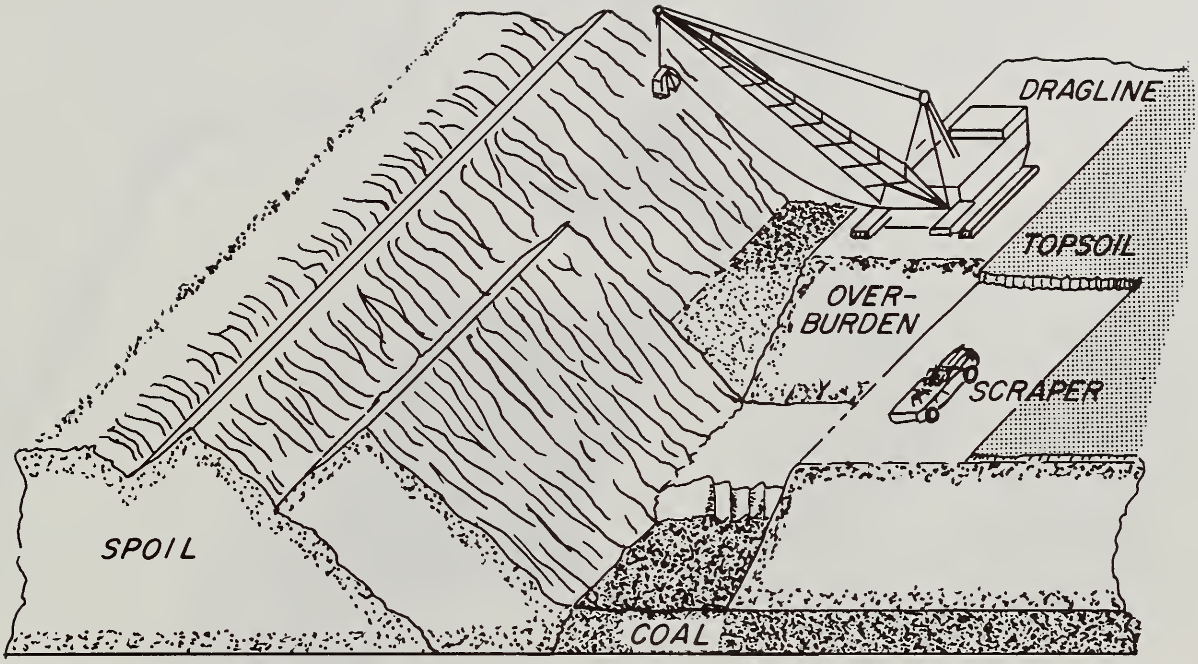


Figure 9a. -- Typical Mining Diagram.

Figure 9b. -- Mining Layout With Stripping Shovel.

PLOTTER, HARDCOPY UNIT, SCOPE, DIGITIZING TABLET

Figure 9c. -- View of Left-Hand Side of System Installation at MSU.

MAGNETIC TAPE DRIVE, C.P.U., DISC DRIVES, CONSOLE, PRINTER

Figure 9d. -- View of Right-Hand Side of System Installation at MSU.

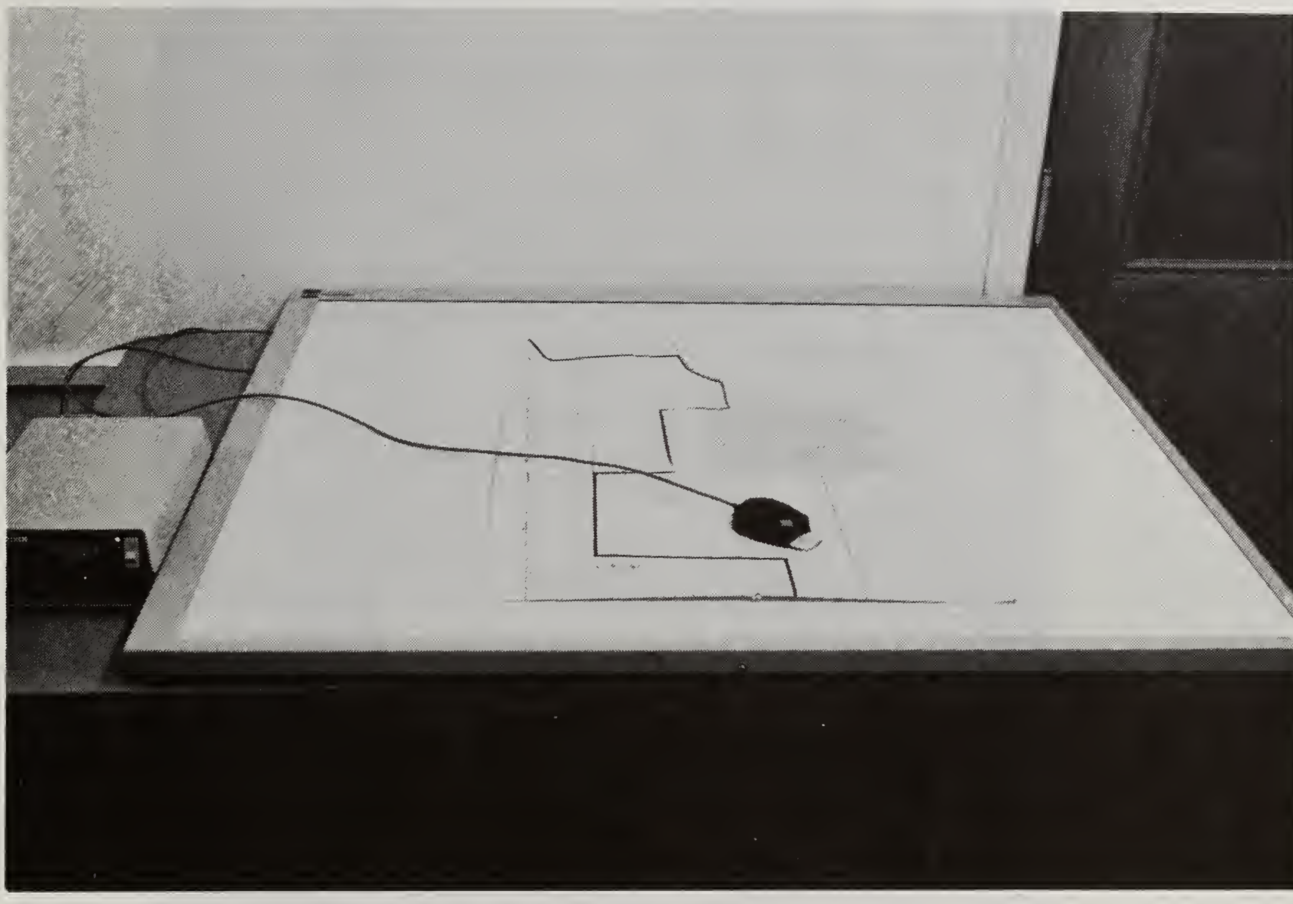
H.P. 7970E DIGITAL TAPE UNIT, H.P. 21MX,
H.P. 7900E DISC DRIVE, H.P. 7920 DISC DRIVE

Figure 9e. -- C.P.U. and Peripherals.

SCREEN SIZE - 14.5 X 10.9 inches

RASTER UNITS - 1025 X 750

Figure 9f. -- Tektronix 4014-1 CRT Control Console.



USEABLE AREA - 40 X 30 inches

GRID POINTS - 4096 X 3120

Figure 9g. -- Tektronix 4954 Digitizing Tablet.

SPEED - 180 characters/second

Figure 9h. -- L.A. 180 Line Printer

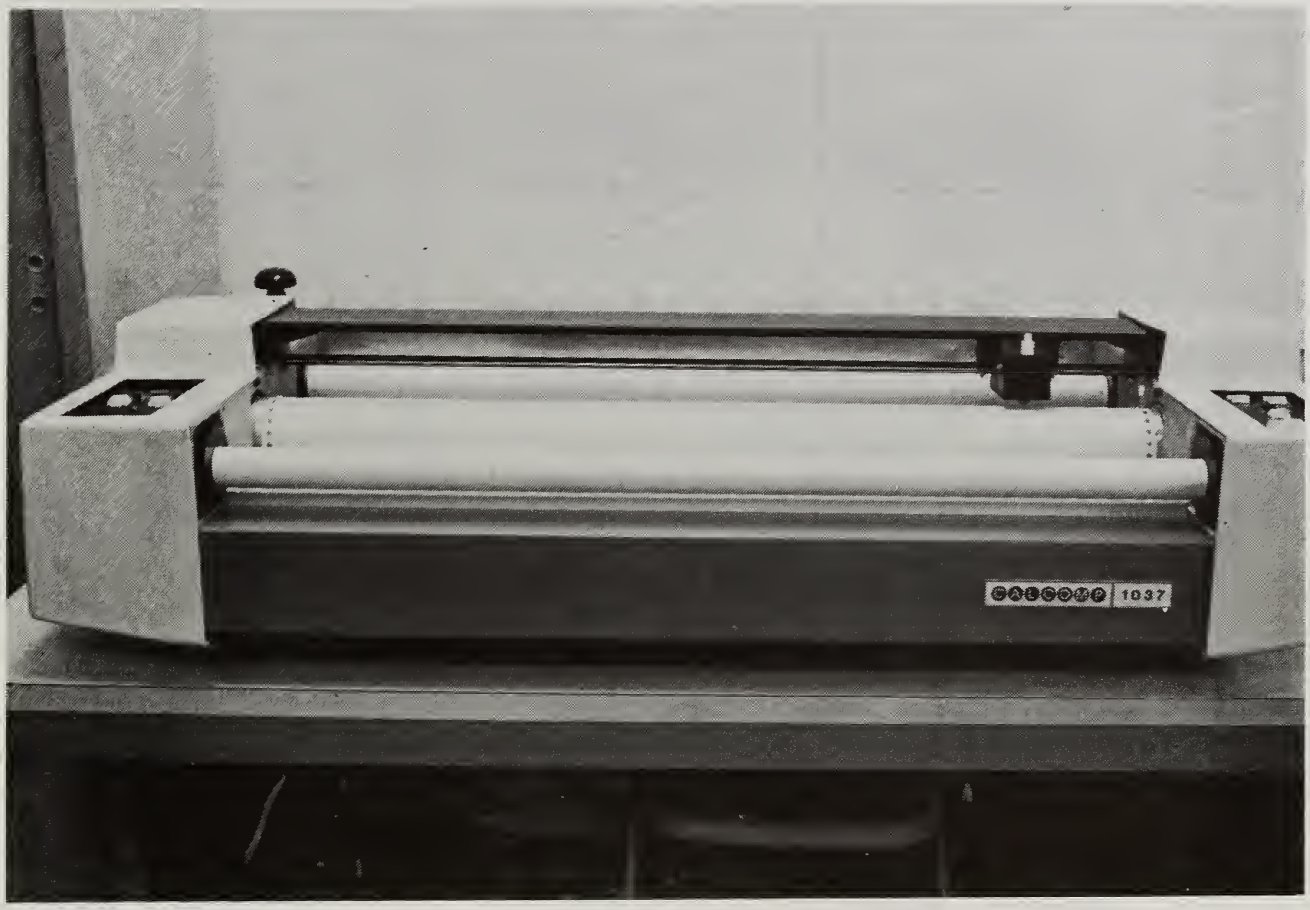


Figure 9i. -- CALCOMP 1037 Drum Plotter.

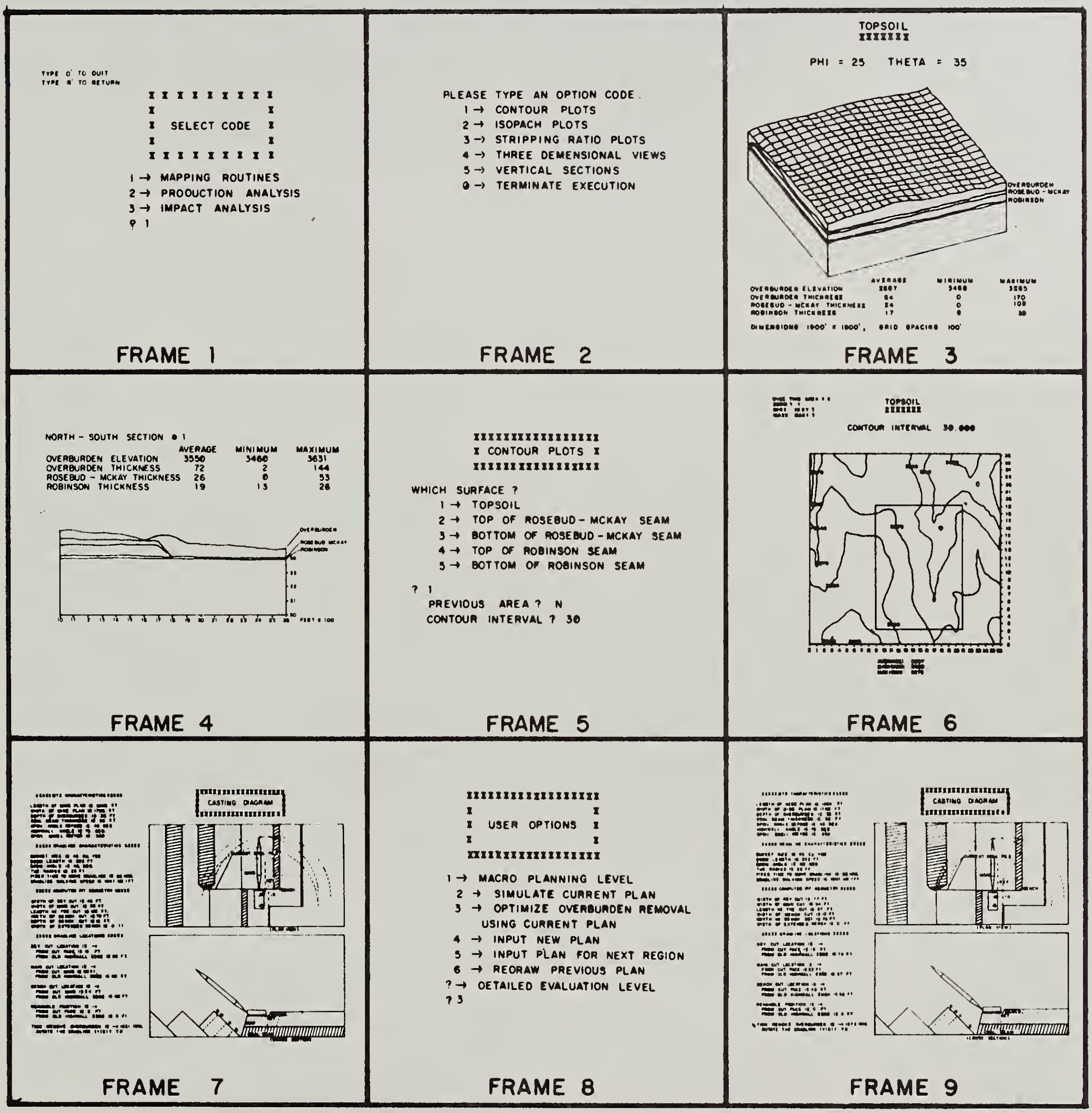


FIGURE 10.-- TYPICAL MINE PLANNING SEQUENCE (OVERVIEW).